Space Technology Research Grants

A Drag Device and Control Algorithm for Spacecraft Attitude Stabilization and De-Orbit Point Targeting using Aerodynamic Drag

Completed Technology Project (2017 - 2021)

Project Introduction

To reduce the accumulation of human-made "space junk", NASA has implemented a rule requiring the disposal of spacecraft below 2,000 km within 25 years. By deploying a device to increase the surface area of a satellite, the aerodynamic drag force will be greater and the maximum altitude for de-orbit within 25 years will be higher. Additionally, for spacecraft containing components that do not disintegrate on re-entry, the only way to obtain a launch is to find some means of controlling the de-orbit location such that the risk of a person being struck by falling debris is less than 1 in 10,000. The first component of the proposed research involves the development of an algorithm to control the de-orbit location of a low Earth orbit spacecraft by modulating the spacecraft's ballistic coefficient. This algorithm could be utilized to control the de-orbit location of any space vehicle capable of varying its cross-sectional area either through changes in attitude or the deployment of a drag device. Ultimately, this will enable spacecraft without thrusters to target a de-orbit point away from populated areas and will enable vehicles with thrusters (such as rocket upper stages) to save fuel by leveraging the available aerodynamic drag to target a de-orbit location instead of performing a de-orbit burn. The majority of the guidance generation portion of this targeting algorithm has already been developed and was based on an analytical solution relating the spacecraft initial conditions and ballistic coefficient profile to the de-orbit location. Using this analytical solution along with an iterative numerical procedure, it is possible to determine the drag profile necessary to de-orbit in a desired location. The guidance tracking portion of the targeting algorithm that will modulate the satellite's ballistic coefficient to maintain the desired decay trajectory (guidance) is currently in development but initial simulation results with a simple PID control law indicate that performance will be satisfactory. Model reference adaptive control techniques will be utilized in future versions of the guidance tracking algorithm to improve performance in the face of discrepancies between the actual and estimated drag force. The second component of this project involves the development of a retractable CubeSat drag device that is capable of de-orbiting a 15 kg satellite from a 700 km circular orbit in 25 years and can be used to actively modulate the spacecraft's ballistic coefficient for aerodynamic orbit control and targeted re-entry. This device will consist of four measuring-tape-style booms inclined at 20 degrees relative to the rear face of the satellite. In addition to providing a means of modulating the ballistic coefficient, the dart configuration of the drag device will make the satellite aerodynamically stabilize in the ram-direction. Furthermore, partially retracting two of the booms opposite each other will result in a clear minimum moment of inertia axis which will naturally align with the nadir vector due to gravity gradient torques. The drag device will ultimately provide 3-axis attitude stabilization as well as orbital maneuvering capabilities using aerodynamic and gravity gradient effects, potentially eliminating the need for propulsion or attitude control systems on many satellites. Additionally, the entirety of the guidance generation and guidance tracking algorithms will be conducted on a microprocessor located inside the

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Table of Contents

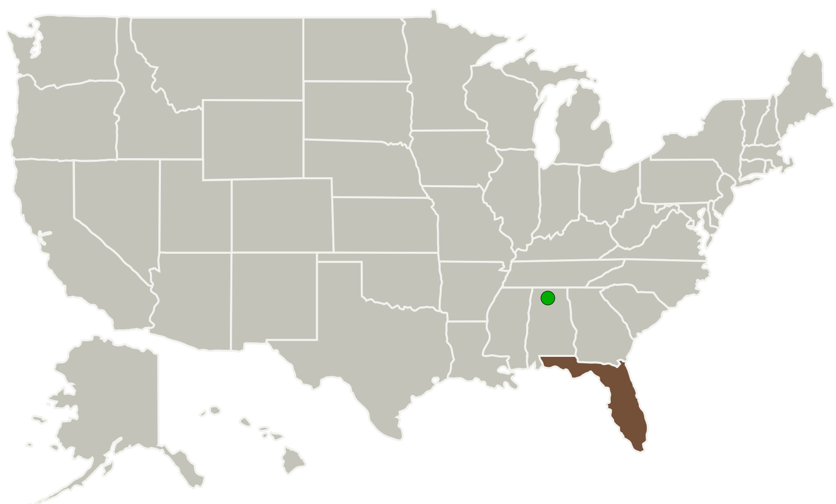
Project Introduction	1
Anticipated Benefits	2
Primary U.S. Work Locations and Key Partners	2
Organizational Responsibility	2
Project Management	2
Project Website:	3
Technology Maturity (TRL)	3
Technology Areas	3
Target Destination	3

drag device. This will minimize ground operator workload but will demand robust and efficient algorithms capable of running on a platform with limited computational power. The team plans to launch a CubeSat in the next 2-3 years to test the drag device and targeting algorithm. A successful flight demonstration will hopefully make the drag device and de-orbit point targeting algorithm standard tools for attitude control, orbit control, and orbital debris mitigation.

Anticipated Benefits

This algorithm could be very useful for orbital debris mitigation and removal.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Florida	Lead Organization	Academia	Gainesville, Florida
Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, Alabama

Primary U.S. Work Locations
Florida

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Florida

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Riccardo Bevilacqua

Co-Investigator:

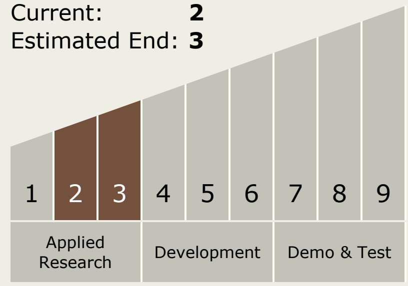
Sanny R Omar

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  - └ TX09.1 Aeroassist and Atmospheric Entry
    - └ TX09.1.3 Passive Reentry Systems for SmallSats

Target Destination

Earth